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Item Description: This is a draft manuscript of a lengthy report compiled by the RAF Bomber Command Operational Research Section, probably some time in 1945. The report was authored by Dr. Basil Dickins, a rising star in the field of physics who served as Section head during the war. Using a thematic approach it explores in excellent detail the challenges inherent in strategic bombing, making it a valuable source for both historians of air power and those studying Europe in the Second World War.

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CHAPTER 5

THE ACCURACY OF BOMBING OPERATIONS

The accuracy of Bomber Command attacks varied greatly from raid to raid, but apart from this wide fluctuation which can loosely be called random, there was a steady improvement right through the war. Yet even if the accuracy had remained fixed, the weight of bombs dropped on enemy targets would have shown a marked increase owing to the increasing scale of effort. In other words, one of the parameters of a bombfall distribution, not discussed in Chapter 2, is 'N', the number of bombs (or aircraft in a photo plot) contributing to the distribution, and in monthly or yearly summation 'N' steadily increased. It seems desirable, therefore, that any account of accuracy should be seen against a background of the scale of effort involved.

The Changing Scale of Effort

Probably the simplest way to convey the changes in effort will be by means of time-charts and Figures 1 to 4,(1) drawn from Air Ministry War Room monthly data, are suitable for this purpose. Figure 1, showing total sorties despatched monthly against all targets, is sufficiently arresting with its 200-fold increase from about 100 per month in the early months of the war to a peak of 21,000 per month in 1945. Attention is drawn to the relative decline to a yearly minimum each January (marked J).

Figure 2, showing the tonnage of bombs dropped, would be still more arresting were it possible to use a vertical scale large enough to show the 1939 tonnages. Actually, the increase corresponding to that of the previous paragraph was some 80-fold. The reason for this is the gradual conversion from light and medium to heavy bombers, which is reflected in Figure 4 (tons dropped per sorties despatched) itself showing a 40-fold increase from about 0.1 to 4.0 tons per sorties. Another factor contributing to Figure 4 is the decreasing abortive-rate, which explains why this figure also shows a slight winter decline.

Figure 3, showing numbers of mines laid monthly, is a reminder that Bomber Command had other tasks besides dropping bombs. In addition there were many leaflet-raids.

Increasing Accuracy

A detailed investigation into trends in accuracy has not been included in this chapter. Figure 5,(2) showing the percentage of aircraft despatched which bombed within three miles of the aiming point, in good and moderate weather, on night attacks on German area targets, will serve as a rough indication of the trend. Unlike the previous curves, this curve has an upper limit at 100 per cent. To avoid excessive fluctuations running averages over six months have been used. It is not considered that this parameter is adequate at values above 75 per cent where a smaller radius such as two miles or one mile would be better but would alter the

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basis of comparison. If data were available for the earlier raids, the point densities referred to above would be the most satisfactory parameter for this purpose.

The accuracy curve should be viewed in conjunction with Figure 1 which, however, includes all targets; the three-mile percentage values would be higher for all targets. Thus the three mile values for April 1943 and April 1945 can be taken as about 30 per cent and 90 per cent respectively, a three fold increase. The corresponding values for sorties despatched are about 6,000 and 21,000, a 3.5 fold increase, so that the absolute numbers of sorties bombing within three miles show an increase of about ten fold.

The increase in accuracy achieved throughout the war against area targets at night was such that whereas before 1943 it was customary to quote the result of a raid in terms of the percentage of aircraft bombing within five miles of the aiming point, by the end of the war the result was assessed by the percentage bombing within one mile of the aiming point. The improvement measured in relation to a one mile radius was even more spectacular than quoted above.

Daylight Operations, 1941 to 1942

Low Level Attacks on Ships

A comprehensive review of the series of low-level attacks on ships carried out by Blenheims of No. 2 Group from March to October 1941 was carried out and published as Bomber Command O.R.S. Report No. 40.(1) (See page 89) In this analysis an estimate of the bombing accuracy was deduced from the probability of obtaining a hit; this probability was calculated from the ratio of hits claimed to bombs dropped. It was found that the probability of hitting increased as the square root of the tonnage of the ship and, using this relationship it was deduced that the probability of hitting for a standard tonnage of 2,500 was 0.13. This corresponded to an average radial error of 50 yards for the average height of 200 feet. This was approximately identical with the pre-war practice bombing results obtained by Blenheims.

Targets in Occupied Territory

The first analysis of bomb accuracy in attacks on land targets covered the period December 1941 to April 1942 and was published as Bomber Command O.R.S. Report No. 41.(2) This dealt only with medium-level, i.e. 6,000 to 15,000 feet attacks carried out in formations of six aircraft with the leader of each vic of aircraft sighting independently and the data used was derived from strike photographs. The attacks were divided into height bands of 2,000 feet width and also divided according to whether much or little opposition was encountered. The analytical procedure employed consisted simply of obtaining the average error in

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(1) A.H.B./IIK/10/46B.

(2) A.H.B./IIK/10/46B.

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line and range, and also radially, of the bombs in each class. It was shown that when little opposition was present the line and range errors were approximately equal and the average radial error for a height of 10,000 feet was of the order of 350 yards. The corresponding peace-time practice error was 200 yards. When much opposition was encountered the average radial error was shown to be approximately doubled, the increase in the range error being greater than that in the line error. There was also an indication that the error increased more rapidly with increasing height in the case of attacks against much opposition.

At a later date a complete review of the daylight operations for the first six months of 1942 was published as Bomber Command O.R.S. Report No. 52.(1) In this a somewhat more refined analysis of the bombing accuracy of medium level attacks was included. The accuracy of the aiming operation was deduced from the position of the centroid of the group of bombs dropped as a result of that operation and the average errors of those centroids were calculated in preference to the average errors of all bombs pinpointed which was used in the earlier note. At this stage a greater subdivision of the degree of opposition could be made and it was found that against no opposition the average radial error for an average height of 11,000 feet was 200 yards, line and range errors being equal. It will be noted that this value is equal to the peace-time practice bombing figure quoted in Bomber Command O.R.S. Report No. 41,(2) but that point was not made in the report. In the presence of any opposition whatsoever the average radial error was doubled, the line and range components remaining equal. Against heavy opposition a further increase in the range error took place but there was no corresponding increase in the line error.

Comparison of the results with those quoted in the earlier paper showed that there had been an appreciable improvement in the accuracy against much opposition and this was attributed to increased experience and to improved technique; in particular the introduction of a Bombing Run Start Indicator which enabled the moment for the turn on to the bombing run to be estimated with much greater precision was considered to have had an important effect. This device was developed by No. 2 Group and consisted of a series of lines drawn on the perspex of the aircraft nose in such a way that by sighting the target from the knob at the top of the height bar of the Course Setting Bombsight Mark IX the moment for turn could be estimated. The details of this device which were set out in an appendix to No. 2 Group's Tactical Report (3) were sent by the O.R.S. to the Instrument Department of the Royal Aircraft Establishment who acknowledged the usefulness of being kept informed of the current problems of the Service and the expedients adopted for their solution.

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(1) Bomber Cmd O.R.S. Rep. No. 52 (Air Min. Scientific Library). (A.H.B./II/39/1)
(2) A.H.B./IIK/10/46B.
(3)

Although No. 2 Group continued to carry out daylight operations of various types until it was transferred away from the control of Bomber Command in May 1943, no further review of bombing accuracy was carried out by the O.R.S. owing to pre-occupation with problems connected with the night bomber offensive which was the Command's most important task at that time. There were, however, a number of special large scale daylight operations carried out during the latter part of 1942 and on one of these, an attack on the armament works at Le Creusot carried out by Lancasters of No. 5 Group on 17 October 1942, results were disappointing. A detailed study of the bombing accuracy was therefore carried out in an endeavour to arrive at the causes of this ~~and this~~ which was published as Bomber Command O.R.S. Report No. S.76.(1) This investigation revealed that there had been a strong tendency to overshoot the target, the centroid of the bomb pattern lying about 400 yards beyond it. (See Page 95) By examination of the raid reports for this operation and discussion with the staff of Headquarters No. 5 Group, it was possible to attribute this result to a combination of causes. Two of these were the failing light, zero hour having been put at 15 minutes after sunset, and smoke from incendiaries dropped early in the raid which together made visual identification very difficult. Another contributory cause was the large number of aircraft going over the target at once and the failure of the force, through lack of practice and experience in this type of operation, to deploy in height and heading as originally planned. Partly as a result of this the heights of aircraft at bombing were in most cases considerably below those laid down, the average discrepancy being 2,000 feet. Since most of the crews were using the Stabilised Automatic Bomb-sight as a pre-set sight this departure from the briefed height would cause an overshoot of about 350 yards. Last minute adjustments may have been made in many cases but these are likely to have led to inaccurate setting-up of the sight. These points were taken into account in planning future operations of this type.

At about this time a small scale investigation into the accuracy of the first attacks by the American VIIIth Air Force was carried out by O.R.S. Bomber Command to provide information for the Air Staff at Bomber Command on the potentialities of the Norden bombsight with which the American aircraft were equipped and of the tactics of day bombing in comparatively large formations. The note that was prepared was not issued as a report since it dealt with the operations of a force which was not part of the Command, but it has been included in the series of Interna Memoranda as No. M.91.(2)

Night Attacks on German Towns from 1940 to end of 1943

Night raids on German towns down to the end of 1943 or early 1944 fall conveniently into three periods, as follows:

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(1) A.H.B./II/39/1/1.
(2) A.H.B./IIH/241/22/3.

(a) Raids prior to August 1941 (when O.R.S. Bomber Command was first established). Not merely are there no valid analyses for this period, but the basic data are too inadequate in both quantity and quality to sustain analysis. The period is to be thought of in terms of few, small, and ill-equipped aircraft making valiant attempts to damage the enemy's economy, but mostly scattering a small bomb-load over a wide area on each raid, and therefore achieving a negligible density of bombs at the aiming point.

(b) Raids from August 1941 to February 1943. Measures of accuracy become practicable during this period, which is interesting as including the introduction of Gee and (later) of the Pathfinder Force but disappointing in that neither of these events lived up to expectations. The only marked improvement visible in Figures 1 to 5 is the increasing tonnage dropped per aircraft despatched, mainly due to conversion to heavies.

(c) Raids from March 1943 to February 1944. This period marks the vindication of the Pathfinder Force, now equipped with Oboe and H2S and using target indicator markers, and includes both the spring and early summer campaign against the Ruhr, using Oboe, and the later H2S campaign against targets outside of Oboe coverage, starting with the series of raids on Hamburg.

Nothing further can usefully be said on the subject of the first period, but the other two merit separate treatment.

August 1941 to February 1943

This period was surveyed over all targets in an O.R.S. report, called 'A review of night bombing operations over a period of 19 months. August 1941 to February 1943', written in March, 1943 but not generally published. It was eventually published as Report No. M.63 (1). This report covers 316 raids and some 38,000 sorties and used as a parameter the percentage within three miles of the aiming point, supplemented by another which is a true measure of dispersion: percentage within three miles of the centre of the concentration. It recognised three distinct sub-periods, briefly dealt with below.

Pre-Gee Period to March, 1942

In this period, with 65 sorties per raid and 68 per cent of the despatched reporting attack, 20 per cent of despatched sorties bombed within three miles of the aiming point (averaged over 147 raids). There is also a dissection by geographical area, by weather (good, moderate and poor), and by moonlight (bright and dark), but it should be noted that this is in terms of attacking sorties which bombed within three miles of the aiming point. These values of the latter parameter for German towns are relevant.

Coastal towns: 33%	of attacking sorties within three miles of aiming point.
Ruhr towns: 14%	
Other inland towns: . 23%	

/Gee Period: ...

(1) A.H.B./IIH/241/22/3.

Gee Period: March 1942 to August 1942

In this period, with 148 sorties per raid and 75% of the despatched reporting attack, 24 per cent of despatched sorties bombed within three miles of the aiming point or 32 per cent of attacking sorties (averaged over 103 raids). The data for German towns are:

	Percentage of attacking sorties within three miles of the	
	Aiming Point	Centroid
Coastal towns:	44%	47%
Ruhr towns:	11%	13%
Other inland towns:	29%	33%

Thus, raids became larger, and the abortive-rate declined; Moreover, the above table shows that raids were well centred, since the three-mile values about the aiming point and the M.P.I. were not widely discrepant. But whilst Gee appeared to have had some beneficial effect on most German raids, those on the Ruhr showed no improvement.

Early Pathfinder Force Period: August 1942 to February 1943

In this period (omitting the highly successful Italian raids), with 214 sorties per raid and 82 per cent of the despatched reporting attack, 24 per cent of despatched sorties bombed within three miles of the aiming point or 29 per cent of the attacking sorties (averaged over 50 raids). The data for German towns are:

	Percentage of attacking sorties within three miles of the	
	Aiming Point	Centroid
Coastal towns:	27%	39%
Ruhr towns:	34%	39%
Other inland towns:	18%	42%

Although raids were still larger and with even fewer abortives, sorties, there was no improvement in accuracy except in the Ruhr.

The discrepancy between the aiming point and centroidal three mile percentages, particularly marked in the case of the more distant targets, clearly underlines the point already made above: the effect of the Pathfinder Force was to increase the concentration of a raid at the expense of introducing a systematic error. Raids were no longer so widely scattered about their M.P.Is. but also were no longer centred on the target. For any given size of target, and a systematic error exceeding the target radius, there was a lower limit to the random error below which further concentration would put fewer bombs on the target. This problem of the systematic error (some theoretical aspects of which were discussed in Bomber Command O.R.S. Report No. 124)(1) constantly engaged the attention of O.R.S. from this time onward.

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(1) [illegible] A.H.B./II/39/1.

The advent of the Pathfinder Force coincided with the jamming of Gee which made the device almost useless over Germany. Moreover, the Pathfinder Force was learning its difficult job and, in this period, had inadequate tools for carrying it out. The period at the end of 1942 and the first two months of 1943 marks a crucial point in the development of Bomber Command. Along with a continuing rise in the ratio of heavies to others and a notable increase in the number of aircraft operational (see Figures 1 and 2)[1], there came almost simultaneously the first operational use of Oboe and H2S, and of target indicator markers leading to the highly satisfactory ground-marking techniques. The effect of these three devices is plainly to be seen in the sudden increase in accuracy during 1943, reflected in Figure 5.[2]

March 1943 to February 1944

While it is true that the 1943 Oboe raids against the Ruhr and H2S raids against more distant targets were of an altogether higher order than earlier attacks, and, for almost the first time inflicted very serious damage on the enemy's towns, it is also true that they still left a great deal to be desired in that they were often badly centred, too dispersed, and of a marked elliptical shape. All these faults were to a large extent corrected later in 1944, but they were very obvious to those studying them in 1943 and they led to the detailed time-analysis of raids described on page 47. This type of analysis initiated the use of standard Gaussian parameters for measuring photo plots, a use which was continued to the end of the war. The parameters will be used in the present section to calculate point-densities as measures of accuracy, though the three percentages will also be quoted for comparative purposes. Finally, factors affecting accuracy which were brought to light and measured by time analysis will be touched on.

The Spring Oboe campaign against the Ruhr, 1943

In an analysis of eight of the major raids in this campaign it was found that on the average there were 657 sorties per raid and 86 per cent of the despatched reported attack. 60 per cent of despatched sorties bombed within three miles of the aiming point, or 70 per cent of the attacking sorties. The latter figure should be compared with the 34 per cent relating to the Ruhr towns above. Moreover, 30 per cent of attacking sorties bombed within the zoned target area. The mean area of the 50 per cent zone (ellipse or circle)centred on the M.P.I. was 7.46 square miles and the mean offset of the M.P.I. (systematic error) was 1.70 miles.

The calculated density at the aiming point (see below for details of individual raids) averaged 63.4 tons per square mile or, in relative form, 37.2 tons per square mile per 1000 tons dropped.

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The autumn H2S campaign against distant towns, 1943

Detailed analysis was carried out on nine of the major raids in this campaign, as a result of which it was found that on the average there were 604 sorties per raid and 87 per cent of the despatched reported attack. 48 per cent of despatched sorties bombed within three miles of the aiming point, or 55 per cent of the attacking sorties. The latter figure should be compared with the 18 per cent related to other inland towns on page 107 and with the 70 per cent for 1943 Ruhr raids. It will be seen, although H2S raids were decidedly less accurate than Oboe raids on this showing, they nevertheless trebled the figure for the type of target concerned, whereas Oboe raids merely doubled the Ruhr figure. Here again, 30 per cent of attacking sorties bombed within the zoned target area, but the targets were larger on the average. The mean area of the 50 per cent zone centred on the M.P.I. was 9.19 square miles and the mean systematic error was 2.29 miles. Thus, these H2S raids were both more scattered and less well centred than the Oboe raids.

The calculated density at the aiming point averaged 51.4 tons per square mile or, in relative form, 31.5 tons per square mile per 1000 tons dropped.

Aiming-Point Densities

Since they are not available elsewhere, it may be useful to list the absolute and relative aiming-point densities for the individual raids analysed, the eight Oboe raids being given first and the nine H2S raids second. As has been explained on page 44, the calculated density at the aiming point is a valuable and steady parameter which is independent of heterogeneity with the distribution and makes use of all the data. This calculated density is given in the left hand columns of the table below for the 17 raids on German cities in 1943 and, on the right hand columns, by way of comparison, for a further 17 raids in 1944 and 1945. The density is given in two forms; the absolute density, in tons per square mile at the aiming point, which takes into account the scale of the attack, and the relative density, in tons per square mile at the aiming point per 1000 tons dropped, which is independent of scale of attack and strictly measures relative accuracy including both centring and scatter.

It will be seen from Table No. 1 that in terms of absolute density a rate of 57 tons per square mile at the aiming point was averaged in 1943, with a range from 3.2 to 216 tons per square mile. The corresponding figures for 1944/45 were 219 tons per square mile on the average, with a range from 23.7 to 658 tons per square mile; thus the average was nearly four times as great. In terms of relative density the 1943 average was 33 tons per square mile per 1000 tons dropped and in 1944/45 it showed a five-fold increase to 174. The 1944/45 data included two daylight raids, in order to be representative, but even excluding these there was an increase in accuracy at night to a value of 122.4 tons per square mile per 1000 tons dropped or 3.7 times the 1943 accuracy.

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TABLE No.1

DENSITY AT THE AIMING POINT - GERMAN CITIES

(Calculated from Raid Parameters)

TARGET	DATE	ABSOLUTE DENSITY (tons/ sq.mile)	RELATIVE DENSITY (per 1000 tons dropped)	TARGET	DATE	ABSOLUTE DENSITY (tons/ sq.mile)	RELATIVE DENSITY (per 1000 tons
Duisburg	26/27-4-43	8.5	5.9	Stuttgart	25/26-7-44	159.1	110.2
Duisburg	12/13-5-43	53.4	36.6	Hamburg	28/29-7-44	48.9	42.4
Bochum	13/14-5-43	21.0	21.1	Russelsheim	12/13-8-44	23.7	24.5
Dortmund	23/24-5-43	35.2	16.3	Bremen	18/19-8-44	108.1	95.6
Barmen	29/30-5-43	84.3	46.6	Russelsheim	25/26-8-44	139.0	89.4
Dusseldorf	11/12-6-43	145.5	72.0	Frankfurt	12/13-9-44	328.2	212.0
Krefeld	21/22-6-43	86.8	44.6	Saarbrucken	5/6-10-44	89.8	54.0
Cologne	3/4-7-43	72.5	40.5	Dortmund	6/7-10-44	305.7	184.3
Mannheim	16/17-4-43	7.5	22.6	Bochum	9/10-10-44	46.1	31.7
Hamburg	24/25-7-43	47.8	20.2	Wilhelmshaven	15/16-10-44	349.8	163.8
Hamburg	27/28-7-43	7.7	3.3	Bochum	4/5-10-44	658.4	198.3
Nurnberg	27/28-8-43	3.8	2.2	Freiburg	27/28-11-44	287.2	169.3
Mannheim	23/24-9-43	28.6	15.4	Ludwigshaven	2/3-1-45	182.6	149.5
Hannover	27/28-9-43	3.2	1.4	Magdeburg	16/17-1-45	238.3	223.5
Kassel	3/4-10-43	39.0	25.1	Nurnberg	2/3-1-45	182.7	87.7
Hannover	8/9-10-43	108.9	64.8	Emden	6/9/44)*	463.6	797.5
Kassel	22/23-10-43	216.1	128.8	Munster	12/9/44)*	110.5	315.7
	AVERAGE	57.1	33.4		AVERAGE	218.9	173.5
					Increase over 1943:	3.8 fold	5.2 fold

* Day raids.

It should be explained that low values in the table are due mainly to bad centring of the raid, and much higher densities were achieved away from the aiming point. Thus, in the Hannover raid of 27/28 September 1943 when the rate at the aiming point was only 3.2 tons per square mile, a rate of 120 tons per square mile was achieved at the M.P.I. which was offset nearly four miles from the aiming point. It is a feature of the 1943 raids analysed that the Oboe relative densities are less variable than those of H2S raids; this is due to the more accurate centring of Oboe as a radar device. Most of the H2S raids were at least planned as Newhaven attacks, but if visibility for the visual markers was poor the raid often became badly centred. Oboe densities were not only less variable but, on the average, higher. Nevertheless, the best attack analysed prior to 1944 was the H2S Newhaven attack on Kassel on 22/23 October; this was one of the most devastated towns in Germany.

Time Analysis factors affecting Accuracy

The Seventeen 1943 raids were subjected to the process of time analysis briefly described on page 47, whereby each five-minute period in each raid was accorded full Gaussian analysis, much as if it were a separate raid. The completion and publishing of this work was contingent upon the publishing of the earlier report, Bomber Command O.R.S. Memorandum No. M.63. (1) ('The nature and use of the photographic sample in night operations') which fully explained the method and examined the validity of the photographic evidence. This report was issued in the Internal Memoranda series. The time-analysis work itself was never completed, being in competition with what were considered more urgent tasks, but some of the data were later issued as Memorandum No. M.97. (2) The following factors may be considered of some interest as affecting the accuracy story.

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Time-concentration

The peak five-minute concentration occurred on the average in the fourth five-minute period and was at the rate of 18.6 aircraft per minute for the eight Oboe raids, 23.1 aircraft per minute for the nine H2S raids, and 21.0 for the whole 17 raids. The corresponding one-minute values (i.e. not averaged over five minutes) were 27.2, 32.3 and 29.8 aircraft per minute, averaged over eight, nine and 17 raids respectively.

'Percentage within three miles' Value

In the Oboe raids this started at 80 per cent but fell off evenly to 52 per cent in the sixth period. Thereafter it showed a marked recovery, partly because a few Oboe raids did recover after temporary ground-station failure, and partly because averaging was done by superimposing zero-hours and raids were of varying length (the latter half of each time-chart therefore shows increasing variability and the first half is the more reliable). In the H2S raids the value fell off from a peak value of 68 per cent in the third period to zero in the eleventh.

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(1) A.H.B.2 unindexed.
(2) A.H.B./IIH/241/22/3.

Thus, on the average, raids started well but quickly deteriorated.

Five-Minute Centroid distance from Aiming Point

This measured deterioration in a different unit, by taking the distance from each five-minute M.P.I. to the briefed aiming point and averaging for that period over raids: it was a five-minute systematic error. Its value was minimal at 0.8 miles for Oboe and 1.5 miles for H2S raids in the first period deteriorating to 2.6 miles in the eighth period for Oboe raids and 5.2 miles in the eleventh period for H2S raids.

Area of Five-minute 50 per cent circle

This, which measured dispersion about the five-minute M.P.I. without reference to the systematic error, was optimal at $4\frac{3}{4}$ square miles in the second period for Oboe and at $6\frac{1}{4}$ square miles in the third period for H2S raids. The worst values were $10\frac{3}{4}$ square miles in the sixth period for Oboe and $14\frac{1}{2}$ square miles in the eighth period for H2S raids. Thus raids not only drifted away from the briefed aiming point but also become more scattered.

The evidence of the last three paragraphs suggests that it was the earlier part of the raid which was valuable; the latter half (more or less, in individual cases) was much less effective. The remedy was to dispense altogether with the latter half by making raids shorter, or to concentrate the whole effort into the first 20 minutes or less. It was a fortunate circumstance that evidence on the losses and aircraft damage side also favoured more concentration in time, and the raids of 1944 became much shorter. Concentration in time was followed by concentration in space, since on most raids the five-minute M.P.I. ceased to drift. Raids, as wholes, became better centred and were more nearly circular in shape. The whole trend is forcibly illustrated by the relative aiming-point densities of Table No. 1.

By March 1944 the long series of precision attacks on tactical targets had fully started with the marshalling yard campaign. This inaugurated an altogether new level of accuracy, with relative aiming-point densities averaging nearly 2,000 tons per square mile per 1,000 tons dropped. Investigations into these by O.R.S. will be described below.

Attacks on Occupied Territory 1943 to 1945

Night Precision Attacks in 1943

In the second half of 1943 a number of attacks were made on factories and similar targets, mainly in France. These attacks were carried out in the moon period against only light defences and it was considered by the Command that a high degree of accuracy would be achieved and that heavy damage to these precision targets would thereby be accomplished. Crater plots were obtained for three of these attacks and analysed, the results being presented in Bomber Command O.R.S. Report No. S.109.(1) These three attacks were carried out using different techniques and it was therefore possible to use the results of this analysis to evaluate the comparative merits of the techniques as well as to detect the defects common to them all. Two of the attacks analysed employed ground-marking techniques and in the remaining one the target was illuminated by flares throughout the attack and the bombing was visual. A number of useful conclusions were reached and recommendations made among which were included:-

(a) When visual bombing was relied on, the target area was rapidly blanketed by smoke and could not be seen. On the other hand the point of aim could be adequately indicated by ground markers.

(b) The average random error of bombing was 400 to 600 yards from 5,000 to 14,000 feet. This was well below the capabilities of the sight.

(c) Marking accuracy was not sufficient to ensure that the main concentration of bombing fell on the target and needed to be considerably improved if the accuracy of the main force was to be taken full advantage of. Increased attention to bombing accuracy by all crews, and particularly by marker aircraft, was therefore required.

(d) An appreciable systematic error in the bombing of the markers could occur and in the case of an attack by No. 4 Group this was apparently due to aiming the first bomb of the stick thereby causing an overshoot.

When this report was issued it was established that No. 4 Group had, in fact, been aiming the first bomb and not the stick centre. A method of introducing the appropriate correction by oversetting target height was sent to the O.R.S. representative at the Group so that he could make the necessary calculations until the Royal Aircraft Establishment computer, which was being developed, became available. In March 1944, however, a more exact formula for calculating this correction was provided by M.A.P. and passed to the Armament Branch of the Command, it being intended that they should calculate tables and issue them as a Bomber Command Armament Staff Instruction. At the same time this formula was transmitted to the O.R.S. representatives at Groups. The calculations were, in fact, performed by O.R.S. at the beginning of May 1944, when an electric calculating machine became available, and were then issued by the Command's Armament Branch as Bomber Command Armament Staff Instruction, Part I, Section J. Leaflet No. 1.(2)

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(1) A.H.B./II/39/1/1.
(2)

During December 1943 and January 1944 a number of attacks were made by Bomber Command on Crossbow (Flying Bomb) targets in Northern France. In some of these operations heavy bombers, either Lancasters of No. 617 Squadron using the Stabilised Automatic Bombsight Mk.IIa or Stirlings of No. 3 Group using the Mark XIV Bombsight, were used, the bombs being aimed at markers dropped by Oboe. The accuracy achieved in these operations was studied using crater plots and marker plots as the sources of data and the results issued as Bomber Command O.R.S. Reports Nos. S.116,(1) S.117,(2) S.123,(3) S.127.(4) The first of these deal with attacks of heavy aircraft and the other two with Oboe bombing raids. These latter, which were purely concerned with the accuracy of Oboe as a device, are discussed in Chapter 13. The general conclusions arrived at from these analyses were:-

(a) The accuracy of bombing with the Stabilised Automatic Bombsight Mk.IIa was about equal to that achieved in practice and in trials. Average radial errors about the marker in the two attacks were 80 yards and 120 yards, the bombing height in both cases being from approximately 13,000 feet.

(b) The bombing accuracy of the crews using the ~~Mk.~~ Mark XIV bombsight was considerably less than that attained in practice and this again was less than that of which the sight was capable, as shown in trials. An average radial error about the markers of about 500 yards was the result obtained from a height of about 13,000 feet.

(c) Owing chiefly to errors in range, almost all of them undershoots, the accuracy of marking was insufficient, with the bombing accuracy achieved, to produce a good concentration of bombs on the target.

At the same time as these investigations were being undertaken, Bomber Command O.R.S. ~~(Bomber Command)~~ and the Air Warfare Analysis Section were collaborating in studying the results of the attacks on gun batteries in the Boulogne area with particular reference to the accuracy of the attacks, and a joint report, Bomber Command O.R.S. No. S.126 (5) and Air Warfare Analysis Section Report No. 52 was produced.(6) The main sources of data used for the Bomber Command attacks were crater plots of target indicator markers. The craters to be attributed to the attacks of other forces which attacked in daylight were distinguished from those due to Bomber Command attacks by the use of strike photographs. It was found in this case also that the average radial error of bombing on the markers was approximately 500 yards but the inaccuracy of the markers, even those dropped in salvo, was spread out over a distance of about one mile in track.

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(1) Air Min. Science Library. A.H.B./IIM/a1/4a App. O.R.S.
(2) Air Min. Science Library. A.H.B./IIM/a1/4a App. O.R.S.
(3) A.H.B./II/39/1/1.
(4) Air Min. Science Library. A.H.B./IIM/a1/4a App. O.R.S.
(5) Air Min. Science Library. A.H.B./IIM/a1/4a App. O.R.S.
(6)

The results of these investigations into the accuracy of operations against precision targets started two lines of attack on the shortcomings revealed. The difference between operational results and practice results with the Mark XIV bombsight, and the further difference between practice results and the potentialities of the sight, caused the O.R.S. to institute enquiries into the reasons for the discrepancy. These enquiries included an examination of the state of training in bomb-aiming and initiated the work on practice bombing described in Chapter 10. In addition data on the winds set on the bomb-sight was obtained in order to discover whether there was sufficient variation in these to account for the increased dispersion of the bombs. It was found that in the attacks on Crossbow targets the vector errors were distributed normally about the mean wind used with an average vector error of about 10 m.p.h.; the average values for individual raids varied between 6 m.p.h. and 17 m.p.h. A vector error of 10 m.p.h. is equivalent to approximately 150 yards on the ground when bombing with H.E. bombs from the heights flown in these attacks. Thus the entire removal of this cause of dispersion would only have reduced the average radial error of bombing from 500 yards to about 475 yards and it was clear that this factor was not of any very considerable importance.

In addition to investigations designed to decrease the dispersion of bombs about the markers, investigations were also directed towards improving the accuracy of marking. These were partly concerned with the accuracy of the Oboe system, and this aspect is covered in Chapter 14. In addition the ballistic characteristics of target indicator markers and the problems of aiming airburst cluster projectiles were studied [illegible] in this section page below. There were also doubts of the stability and ballistic consistency of target indicators and bombs when released from the heights and at the speeds used on Oboe operations and these points also were investigated. [illegible] in Chapter [illegible]

Attacks in Support of the Campaign in Northern France and Belgium, 1944

As far as Bomber Command was concerned the tactical campaign which prepared the way for and assisted the landings in Normany and the subsequent land operations began with a series of operations against marshalling yards in France and Belgium and continued throughout the summer with attacks on coastal batteries, road choke points, ammunition depots, troop and mechanical transport concentrations and airfields. In June, July and early August also a very considerable amount of the Command's effort was expended against the launching points and storage sites for flying bombs. Throughout the whole of this period a close watch on the

/accuracy

accuracy of bombing that was being achieved was necessary in order to ensure that, in view of its manifold tasks, the force at the Command's disposal was used to the fullest advantage. This series of attacks opened with the attack on Trappes Marshalling Yard on the night of 6/7 March 1944 and from that date O.R.S. was busily occupied for several months almost entirely in quantitative analysis of these attacks in order to provide the Air Staff of Headquarters Bomber Command with detailed information of the results being achieved and with suggestions for improvement.

The Attacks on French and Belgian Marshalling Yards March to April x 1944.

The work done on the accuracy of this series of attacks was of two types. An immediate examination of each attack designed to elucidate its structure and to determine the extent to which it had succeeded in its object was undertaken and also a detailed analysis of the crater plots was carried out which enabled a comprehensive review of the bombing accuracy achieved in this campaign to be made. The immediate examinations were published as the series of reports and summaries described on page 38 . In these reports there was included a comparison between the results achieved expressed both as hits per acre of the target area and as percentage of bombs despatched falling on the target and the expectation based on the accuracy assumed in planning this series of operations. These comparisons gave an overall measure of the accuracy which was being achieved but, without the more detailed analysis which required more time, the causes of differences could not be fully elucidated.

In these reports and summaries the actual achievement was measured by direct counts of the craters visible on plots made by 'K' Section of the Allied Central Interpretation Unit and, as was pointed out on page this leads to an underestimate of the result due to a proportion of the craters being missed. However, in Bomber Command O.R.S. Report No. S.159,(1) in which the results of the first 15 attacks are discussed this fact is considered and allowance made for these missed craters. When this was done it was found that the results achieved were only 72 per cent of those expected. The reasons for this discrepancy only became apparent, however, as a result of the detailed analysis of crater plots.

This detailed analysis is fully described both as to the methods employed and the results obtained, in Bomber Command O.R.S. Report No. 167 (2). It is desirable, however, to summarise the findings here as a preliminary to recording the subsequent action. There were:-

(a) The proportion of gross errors was 27 per cent, this large figure being mainly due to gross marking errors which attracted bombs away from the main clusters.

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(1) A.H.B./II/69/231(b), Encl.91A.
(2) A.H.B./II/39/1/1.

(b) The average overall systematic error was 485 yards. The average error of the markers was 330 yards which was of the expected order but the M.P.I. of the bombing was appreciably displaced from the markers, its average distance being 350 yards from them. This displacement showed a starboard bias of 200 yards but greater variation in range than in line. Flat turns were suggested as the possible cause of the starboard bias and incorrect target pressure settings and fake height settings to correct for stick length to account for the spread in range.

(d) The radial standard deviation of the bombs about the M.P.I. averaged 540 yards. Even after correcting for the increased dispersion in range due to the bombs being dropped in sticks it was found that the random errors in range were slightly larger than those in line. This spread was considerably greater than current practice results and although the gap was narrowed when allowance was made for the spread of markers within the groups aimed at and also the variation in winds used, it was still considerable.

This report was drafted by 16 May 1944, but, for a variety of reasons, was not issued until more than two months later. The results of the analysis were, however, available to the Armament and Training Branches of the Command and also to M.A.P. even before the draft was completed and much was done to bring about improvements. The drive on marking accuracy using Oboe which was stimulated by the reports on the individual attacks is described in Chapter 14 and in Chapter 3 the improved marking technique with the use of a Master-Bomber is discussed. The recommendation that automatic observers should be installed in some aircraft of the main force in order to check the quality of the flying during the bombing run was passed to the Armament Branch on 7 May and implemented by them.

Another result of this analysis was an informal meeting on bombing accuracy problems held at M.A.P. on 5 May 1944, under the chairmanship of the Assistant Director of Research (Research and Development Instruments 2). It was at this meeting that the suggestion was made that the variation in range of the M.P.I. of the bombs relative to that of the markers should be investigated. This meeting was also of the opinion that increased training and practice in bomb-aiming were required and that the analysis of bombing practices should be more carefully controlled so that the causes of errors would be detected. This opinion was by no means confined to those present at the meeting, but was shared by all who were concerned with the problem. It resulted, amongst other things, in the setting up of the Bomber Command Analysis School on the initiative of the Command's Training Branch and in the general drive on bombing accuracy and bomb-sight maintenance.

It was this general drive on bombing accuracy which was without doubt the most fruitful of the various measures taken at this stage. More frequent practices, better maintenance and, above all, the engendering in the aircrews of an enthusiasm to attain the maximum possible accuracy on

/operations,

operations, produced great and rapid improvement which was stimulated by a healthy amount of inter-group rivalry. Knowledge of the difference between what was being achieved and what might be was the basis of this propaganda and since that knowledge was provided by the analysis carried out by O.R.S.## they can claim a considerable share of the credit for the improvement which took place.

Attacks on Tactical Targets, May to September 1944

The extent of this improvement was revealed by the further analyses of crater plots on various targets in France attacked during the summer. The results of these were issued as a series of reports on the accuracy of groups within the Command and summarised in Bomber Command O.R.S. No. S.184.(1) In these reports it was shown that the overall systematic error was reduced on the average to about 300 yards and the starboard bias was eliminated. The random error was also reduced so that the radial standard deviation about the M.P.I. became on the average approximately 440 yards. The reduction in the overall systematic error was due not only to improved marking accuracy and a smaller systematic error in bombing the markers but also to the influence of the Master Bomber, when there was one, in counteracting to some extent the errors in marking.

From these later investigations, which showed that so satisfactory an improvement had taken place, further steps to produce improvements did not, as in the earlier case, ensue. Their value was principally in providing definite information on what the Command was likely to achieve thereby enabling the operations of the Command to be planned with some precision. This was of particular value in delineating a bomb-line in attacks carried out in close support of the ground forces. An account of the work of O.R.S.## in this and similar directions will be found in Chapter #6.

In addition to the detailed analyses of crater plots, which could only be carried out for a comparatively limited sample of raids, counts of the craters within a 20-acre circle centred at the aiming point were made for some 200 raids during this period. The results were expressed as bombs per acre per 1000 dropped, a measure referred to as the relative density. Two detailed reports based on statistical analyses of these relative densities were prepared, one covering night attacks in the period March to June X 1944 and the other covering day attacks from June to September X 1944. These reports were not published at the time but a summary of the two was issued as Bomber Command O.R.S. Report No. S.192.(2) The two full length reports were, however, later included in the series of Internal Memoranda. These reports were concerned principally with comparison of the various techniques of attack employed, but they also considered the effect of the height of attack, the weather, and the defences on the accuracy of bombing and compared the accuracy of the difference groups. The reports on the day attacks, Nos. S.182 (3) and 183, (4) made

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(1) A.H.B./II/39/1/1.
(2) A.H.B./IIH/253/1/290b.
(3) A.H.B./II/39/1/1.
(4) A.H.B./IIM/al/42 (Bomber Cmd. O.R.B. Appx., Jul. 1944).

strong recommendations in favour of formation Oboe and No. 5 Group visual marking techniques and a comment may perhaps be permitted on this point. No mention is made in the report of the fact that if further operations were confined to these techniques almost 75 per cent of the Command's operational force of heavy bombers could not have been used. The weight of attacks made by formation Oboe was also very severely limited. If the findings of this report were to lead to any improvement they needed to contain some suggestion of the ways in which it might be possible to make the results of attacks in which the main and marker forces were drawn from Groups, other than No. 5, approached more closely those obtained by that group.

The Attacks on Coastal Batteries, May to June 1944.

The investigations discussed in the last three paragraphs dealt with the whole of the Command's effort against small targets in France and the Low Countries. These were supplemented by an examination of the attacks on coastal batteries which were carried out in the month preceding the landing in Normandy. This examination, which was undertaken in order to provide the Air Staff of Bomber Command with information necessary for the planning of the attacks on the night of the landing, was based on counts of craters within a 20 acre circle about the aiming point and reports, provided by the Allied Central Interpretation Unit, of the damage sustained by the guns. As a result of this examination the use of Oboe ground-marking on that night was considered to be desirable since it was less susceptible of being disturbed by adverse weather conditions. With the use of this technique an effort of 100 sorties was deemed sufficient for an adequate expectation of doing the requisite amount of damage to a battery. The memoranda prepared at this stage for the Air Staff were included in the series of Internal Memoranda as Bomber Command O.R.S. Nos. M.105(1) and M.106.(2) In spite of thin cloud on the night of 5/6 June the attacks succeeded sufficiently to ensure that artillery opposition to the landings was not serious.

A review of these attacks was issued by the R.A.F. Bombing Analysis Unit after that unit had commenced ground survey work in France as B.A.U. Report No. 10.(3) This report, which was intended to serve as a background for the accounts of the ground survey of individual batteries, was based on photographic reconnaissance data. Since this report was in many respects at variance with the conclusions of O.R.S. Bomber Command on this series of attacks a report, Bomber Command O.R.S. Report No. S.207(4) was prepared in which the O.R.S's views were set out. Following discussion with the Bombing Analysis Unit the greater part of the differences were resolved and both parties agreed on an appendix to the staff study on the 'Fire Support of Seaborne Landings' prepared by the Joint Technical Warfare Committee.(5)

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(1) A.H.B. II H/241/22/3.
(2) A.H.B. II H/241/22/3.
(3) A.H.B. II S/136/1-10.
(4) A.H.B./II/39/1/1.
(5) A.H.B./I D5/50/5.

It was also agreed in the course of these discussions that the Bombing Analysis Unit would issue an amended and corrected version of ~~their~~ its Report No. 10.

Operations with the Stabilised Automatic Bombsight Mark IIa

The operations carried out by No. 617 Squadron, using the Stabilised Automatic Bombsight ~~Mk.~~ Mark IIa, were studied at the same time as those of the ordinary squadrons of the Command using the Mark XIV sight and the results were presented in Bomber Command O.R.S. Report No. S.184.(1) This report did nothing more than give figures for the accuracy achieved and made no recommendations.

Towards the end of 1944 No. 9 Squadron, using the Mark XIV bombsight, began like No. 617 Squadron, to carry out squadron precision attacks on special targets using the Tallboy bomb. The results achieved by these two squadrons thus provided a comparison of the possible accuracy of the two bombsights under similar very favourable operational conditions and such a comparison is made in Bomber Command O.R.S. Report No. S.226.(2)

In February 1945 No. 617 Squadron came to the conclusion that they were getting a consistent overshoot on operations and therefore proceeded to put a false setting on the sight in order to correct for this. When Bomber Command O.R.S. Report No. S.226 was issued it stated that the results of their analyses confirmed the existence of the overshoot and justified the false setting. Research and Development (Instruments 7 and Armaments 14) of the Ministry of Aircraft Production, however, demonstrated by an analysis of variance that this conclusion could not be arrived at on the basis of the available evidence and that the statistical procedure used by O.R.S. ~~M~~ was faulty. They showed that, in range but not in line, the variance of the means of attacks, i.e. the between raids variance, was significantly greater than that within raids. It was therefore inappropriate to consider the distribution about the aiming point of the bombs from different attacks as a single one and to test the significance of the separation of the compound M.P.I. from the aiming point on that basis. It was thus clear that there was some factor causing substantial errors in range which was constant for a particular raid, but there was no evidence that there was any constant bias in its operation. An amendment to Bomber Command O.R.S. Report No. S.226 was therefore issued.

Attacks on Germany 1944 to 1945

The work done by O.R.S. Bomber Command on bombing accuracy after the conclusion of the summer campaign of 1944, and when almost all targets came once more to be located in Germany, carried on the methods previously used and does not call for any extended treatment. In December 1944

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(1) A.H.B./II/30/1/1.
(2) A.H.B./II/30/1/1.

Bomber Command O.R.S. Report No. S.197 (1) was issued. This was based on six crater plots, five of raids which employed the Newhaven marking technique (see page 62) and one Oboe ground marking. This report showed that the errors were considerably greater than in the attacks on lightly defended targets in France and the Low Countries, but nevertheless they showed a very great improvement over the results of 1943.

Bomber Command O.R.S. Report No. S.209 (2) covered a series of 16 day attacks carried out during the period September to December 1944. The information was based, for some attacks, on crater plots and, for others, on plots of the distribution of bomb-fall made by plotting forward from the photograph taken at the moment of bomb release. The attacks discussed in this report were all comparatively shallow penetrations and the marking was, in most cases, done by Oboe. A number of interesting conclusions were drawn in this report, the most interesting, probably, being that whilst the intensity of flak opposition affected the proportion of gross errors it had no effect on the accuracy with which those bombs which are not gross errors were dropped. It was also shown that the systematic errors were no larger than those which had occurred in comparative attacks on France and the Low Countries, but that there was an increase in the random errors about the M.P.I. greater than could be accounted for by the increased height of attack. In addition there was a significant tendency for the M.P.I. of the bombing to lie to starboard rather than to port, its average position in line being about 200 yards to starboard. This starboard bias occurred in the attacks carried out in March and April 1944 on French and Belgian marshalling yards, but had disappeared when other errors had been reduced.

These two reports did not lead to any improvement, but they, along with the less precise figures derived from plots of night photographs, did provide the information on which to base calculations of force requirements and probabilities of success which were in considerable demand at this time (see Chapter 6). The average figures for the proportion of gross errors, the systematic error and the random error for each type of attack were kept continuously available for this purpose. These did not usually change much and those in use at a particular date in February were published as Bomber Command Report No. B.232.(3)

There was an appreciable lag in the preparation of crater plots, particularly during the early months of 1945, when this work was being done by R.A.F.8 and was in competition with a number of more urgent tasks which they were required to perform. As a result information concerning a considerable number of attacks came to hand after the conclusion of hostilities, when there was no longer the same urgency for making results available. The opportunity of combining the publication of this additional

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(1) A.H.B./II/39/1/1
(2) Ibid.
(3) A.H.B./II/39/1/2.

data with a comprehensive review of the information obtained from crater plots was therefore taken and Bomber Command O.R.S. Report No. S.237 (1) was issued. This included a tabulation of the average figures for the various error parameters for each technique of bombing.

In this report the effect of height on bombing accuracy was considered. It was found that the range of heights of the attacks on German targets was too limited for such an investigation and it was therefore necessarily confined to the results of the attacks on France and the Low Countries. From these attacks three series of about ten each were available, each series consisting of comparable attacks in that the marking technique and general conditions of attack were the same. There were, however, appreciable differences between the accuracies of the different series. The correlation of each of the three error parameters, proportion of gross errors, systematic error and random error with height was then examined for each series. For gross errors and systematic errors it was found to be negligible in all cases but there was considerable positive correlation between random errors, expressed as the radial standard deviation about the M.P.I., and height for each series. Since this was of the same order in all three cases it was considered reasonable to combine all three series and obtain thereby a sample large enough to give more precise information on the nature of the relationship. In order to obtain comparable figures for this purpose, the radial standard error for each individual attack was divided by the average value for the series of attacks to which it belonged. A highly significant correlation between the resulting ratios and the height of attack was found.

The height error relationship in bombing has normally been considered to be a power law of the type:-

$$\text{Error} = a\,h^{x}$$

where a is a constant, h is the height and x has a value less than 1. In order to obtain a value for x the logarithms of the height and the random error ratio were obtained and the regression co-efficient of the latter on the former was determined. This, which was 0.24, is the required figure. The value so obtained can, however, only be regarded as a first approximation since the average heights of attack for the different series of raids differed. The average value of the radial standard error for each series of attacks was therefore corrected to 10,000 feet from the average height for that series using the relationship that error was proportional to the fourth root of the height. The calculations were then repeated and the value of the regression co-efficient obtained then became 0.27. This figure which had a standard error of 0.066 was the best that could be deduced from the data available. Whilst appreciably less than the figure

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(1) A.H.B./IIM/a1/6a (Nov. 1945).

of 0.36 derived from practice bombing results it was not significantly different from it.

The other subject discussed in this report is that of the systematic starboard bias of about 200 yards which was found to have occurred in more than one series of attacks. It was pointed out that it occurred when the random errors of bombing were greater than the best obtainable and it was suggested that the principal factor concerned was the standard of flying during the bombing run. If this were the case, it would indicate that when the pilot's attention to detail in the technique of his flying was somewhat relaxed yaws to port occurred with much greater frequency than yaws to starboard.

A further investigation, published as Bomber Command O.R.S. Report No. S. (1), that was not completed until after the conclusion of hostilities, was one into the distribution of systematic errors with different marking techniques and in different conditions. This investigation had two aims, to ascertain the comparative merits of the various marking techniques in indicating the correct point of aim, and to discover whether there was justification for the assumption made in force requirement calculations that the M.P.Is of bombfall in a series of attacks using the same technique and in the same conditions would be distributed about the aiming point in accordance with the normal radial probability law. All available data from crater plots, plots of night photographs and plots made from photographs taken at bomb release for a period of 12 months was used. The detailed comparison of the various techniques will be found in the report. For the investigation of the normality of the distribution it was necessary to make use of all the information together, owing to the comparatively small number of attacks carried out by the same technique and in comparable conditions. This was done by calculating the radial standard deviation of each comparable group of M.P.Is. about the aiming point and dividing the individual values by this figure. The radial error of each M.P.I. was thus expressed as what might be termed a normal radial deviate. The numbers of these in successive annuli were compared with the expected number as given by the formula for the normal radial distribution and the significance of the difference examined by a chi-squared test. The result of this test was to show that there was no significant departure from normality and the assumption of normality therefore appeared justified.

In the winter of 1944/45 a considerable proportion of Bomber Command's effort was expended in attacks carried out through 10/10ths cloud and it was therefore desirable to try and obtain a comparative measure of the accuracy achieved in such conditions and in clear weather. An attempt to do this was made using the estimates of tons of bombs falling per kilometre square prepared from studies of the amount of damage made by R.E.8. As a preliminary to this the distribution of attack so deduced

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was compared with the distribution of night photographs in the case of a small number of attacks carried out in clear weather. The discrepancies were so large that it was clear that further investigation into the reliability of the data was required. ~~This is still in progress at the time of writing and~~ No conclusion ~~has~~ appears to have been reached and ~~As a result~~ therefore recourse ~~had to be~~ was made to the limited number of crater plots for such raids and a report, Bomber Command O.R.S. Report No. S. 237 (1), based on these, was prepared in which it was shown that such raids were appreciably less accurate than those carried out in clear weather, particularly as regards systematic errors.

In Reports Nos. S. (2) and S. (3) attacks carried out by bombing in formation were omitted since these were studied separately by O.R.S.5 who were concerned with the accuracy of radar devices. These were reported on in Bomber Command O.R.S. Report No. S.211 (4) which is discussed in Chapter 3.

(1) A.H.B./IIM/91/6a (Nov. 1945).
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(4) A.H.B./II/39/1/1.